

# Software Systems for Prediction and Immediate Assessment of Emergency Situations on Municipalities Territories

**L V Poluyan<sup>1,2</sup>, E V Syutkina<sup>2</sup> and E S Guryev<sup>1,2</sup>**

<sup>1</sup>Science and Engineering Centre "Reliability and Safety of Large Systems and Machines", Russian Academy of Sciences, 54-A, Studencheskaya st., Yekaterinburg 620049, Russia.

<sup>2</sup>Ural Federal University named after the first President of Russia B.N. Yeltsin, 19, Mira, Yekaterinburg 620002, Russia.

E-mail: sec@wekt.ru

**Abstract.** The comparative analysis of key features of the software systems TOXI+Risk and ALOHA is presented. The authors made a comparison of domestic (TOXI+Risk) and foreign (ALOHA) software systems allowing to give the quantitative assessment of impact areas (pressure, thermal, toxic) in case of hypothetical emergencies in potentially hazardous objects of the oil, gas, chemical, petrochemical and oil-processing industry. Both software systems use different mathematical models for assessment of the release rate of a chemically hazardous substance from a storage tank and its evaporation. The comparison of the accuracy of definition of impact areas made by both software systems to verify the examples shows good convergence of both products. The analysis results showed that the ALOHA software can be actively used for forecasting and immediate assessment of emergency situations, assessment of damage as a result of emergencies on the territories of municipalities.

## 1. Introduction

Complexity at risk assessment is that it is difficult to assess damages adequately because of lack of reliable information. Numerous casual parameters (climatic conditions (wind and snow loads), dangerous substance characteristics (mixture or homogeneous state), equipment wear rate, etc.) exert influence on the damage scope. Risk determination with taking into account all the factors is a difficult task demanding use of methods of mathematical modeling for these parameters including interval damage estimation at the final stage [1-5]. From all the range of casual parameters exerting impact on risk magnitude the most significant ones are equipment defects, wear rate leading to its depressurization, hazardous substances emissions and emergencies development [6-10].

In this research work the authors made a comparison of domestic and foreign software systems that allowed giving quantitative assessment of impact areas (pressure, thermal, toxic) in case of hypothetical emergencies in PHOs of oil, gas, chemical, petrochemical and oil-processing industry.

## 2. Comparative analysis of the software systems TOXI+Risk, ALOHA

The comparative analysis of the software systems on emergency risk assessment and emergency prediction - domestic software TOXI+Risk [11,12] and foreign software ALOHA 5.4.6 (further in the text – TOXI/TOXI+Risk, ALOHA) [13] - is presented. The software ALOHA is elaborated and



supported by Emergency Response Division under National Oceanic and Atmospheric Administration in cooperation with Department of Emergency Services and Environmental Protection Agency, the USA [14]. ALOHA software is intended for chemical emissions modeling for emergency rescue services and designers. It models toxic gas clouds, flammable gas clouds, BLEVEs (explosions of expanding boiling liquid vapors), torch burning, pool fire and fuel-air mixture explosions [15-17]. The domestic software system TOXI+Risk is intended for assessment of consequences of emergency emissions of hazardous substances and analysis of the emergencies risk that is used at designing and declaring of industrial and fire safety [12]. Key features of both software systems are shown in the Table 1.

**Table 1.** Comparison of key features of the software systems.

| Comparison criterion  | TOXI+Risk:<br><i>Module TOXI</i> | TOXI+Risk:<br><i>Module Fuel-Air Mixture Explosion</i> | ALOHA     |
|---|----------------------------------|--|-----------|
| Database of hazardous substances  | ✓ (>50)                          | ✓  | ✓ (>1000) |
| Calculation of flowage parameters   | ✓                                | ✗  | ✓         |
| Considering the area parameters   | ✓                                | ✗  | ✓         |
| Considering the parameters of the spillage surface                                    | ✓                                | ✗  | ✓         |
| Calculation of spillage parameters  | ✓                                | ✗  | ✓         |
| Considering the equipment parameters  | ✓                                | ✗  | ✓         |
| Considering the information on the emergency scenario                                 | ✓                                | ✗  | ✓         |
| Calculation of heavy gases  | ✓                                | ✓  | ✓         |
| Considering the wind direction  | ✓                                | ✗  | ✓         |
| Calculation of risk parameters  | ✗                                | ✗  | ✗         |
| Calculation of consequences of influence of shock waves at fuel-air mixture explosion | ✗                                | ✓  | ✓         |
| Calculation of consequences at fires  | ✗                                | ✗  | ✓         |
| Development of new substances   | ✓                                | ✓  | ✓         |
| Calculation of mixture of substances  | ✗                                | ✗  | ✓         |
| Convenience of visual representation  | ✓                                | ✓  | ✓         |
| Possibility of carrying out calculations for any amount of the substance              | ✗                                | ✗  | ✓         |
| Interface for information input recommendations                                       | ✗                                | ✗  | ✓         |

Impact areas calculated in ALOHA can be displayed on the maps in MARPLOT® of the other software of CAMEO program family [13]. They can also be displayed in Google Earth or Google Maps by using the functions of export of Esri's ArcMap or ALOHA ArcMap.

The database of ALOHA consists of more than 1000 substances that is much larger than in TOXI software, but in TOXI+Risk software there is an option of development of a new substance. ALOHA is in free access in the Internet that allows using it widely by expert organizations, when training at university courses [18], by civil defense departments of municipalities, etc.

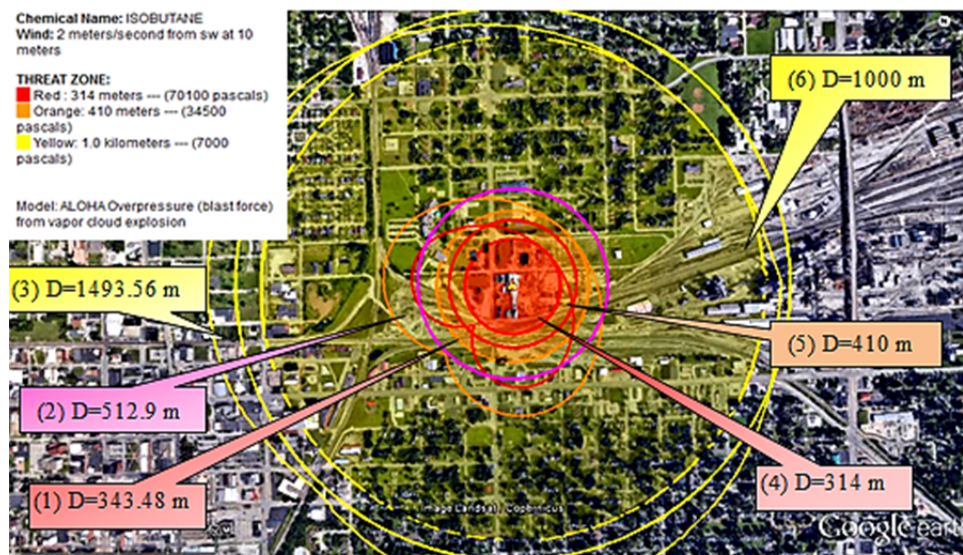
### 3. Examples of comparative analysis of the software systems TOXI and ALOHA

Testing of models concerned only impact areas at emergency emissions of hazardous substances.

1. On the example of the verification emergency in Decatur the calculations are performed in both software systems.

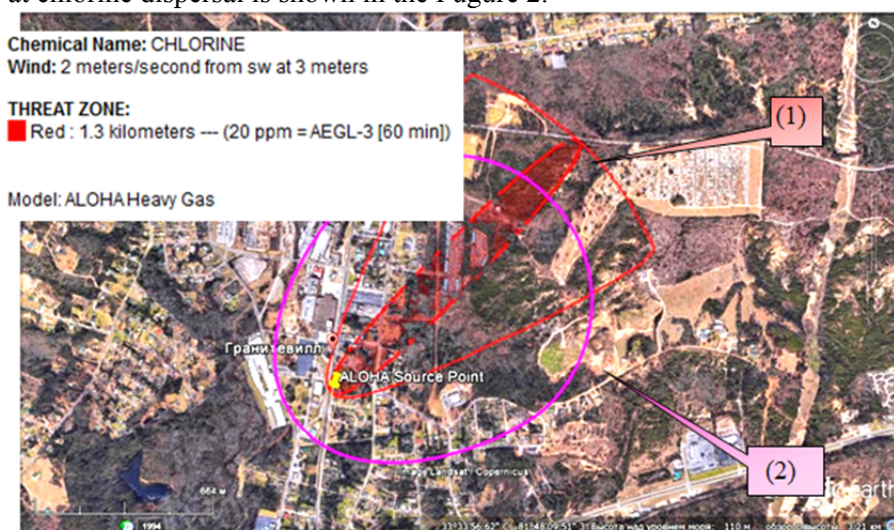
Initial data are: total volume released – 69 t, break-through parameters - width 56 cm, length 66 cm, exposure time - 10 min, environment temperature - 20 °C, area type - very cluttered [19]. In the

Figure 1 superposition of impact areas at isobutane dispersal is shown. Here and in the following figures the significance of «conditional diameter» differences is given in percent.



**Figure 1.** Superposition of impact areas at explosion of isobutane fuel-air mixture in TOXI and ALOHA software systems (area of complete destruction of buildings (9%): (1) – TOXI, (4) - ALOHA; area of heavy destructions of buildings (25%): (2) – TOXI, (5) – ALOHA; area of complete divided glazing (49%): (3) – TOXI, (6) - ALOHA).

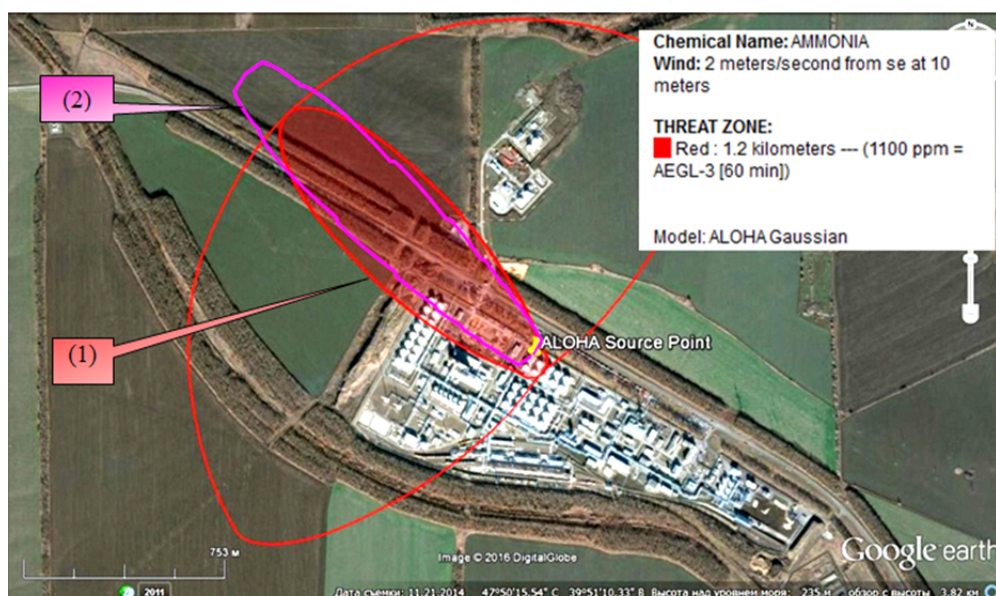
2. The second calculation of the verification emergency with chlorine emission is carried out for assessment of toxic impact areas. Initial data: environment temperature - 13°C, model - hazardous substance emission into the atmosphere, terrain type - centres of towns, atmosphere stability class - F, wind speed - 2 m/s, direction – SW; total volume released - 60 t, substance temperature - -3.3°C, break-through parameters - width 15 cm, length 90 cm, exposure time - 10 min. [20]. Superposition of impact areas at chlorine dispersal is shown in the Figure 2.



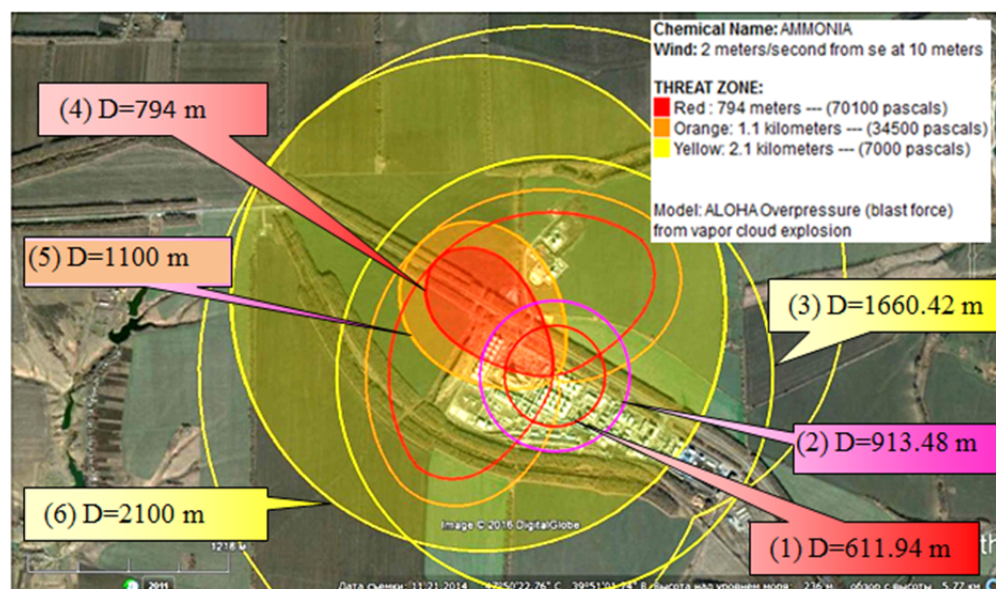
**Figure 2.** Superposition of impact areas at chlorine dispersal in the atmosphere in ALOHA (1), TOXI (2) - (7%).



3. We consider ammonia as a heterogeneous substance. Initial data are: environment temperature - 20°C, model - hazardous substance emission into the atmosphere, fuel-air mixture explosion; terrain type - centres of towns, very cluttered area; atmosphere stability class - F, wind speed - 2 m/s, direction - SE, substance volume - 700 m<sup>3</sup>, exposure time - 60 min. The results of calculations for areas of toxic and explosive damage for liquefied ammonia are shown in the Figures 3, 4 respectively.

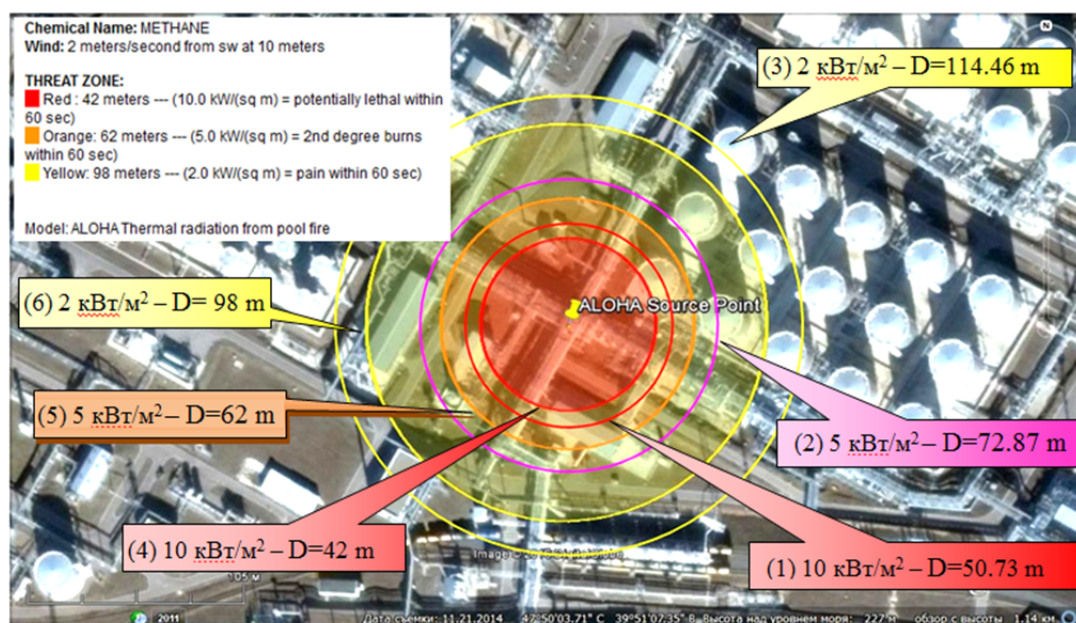


**Figure 3.** Superposition of impact areas at ammonia dispersal in the atmosphere in ALOHA (1) and TOXI (2) software systems - (7%).



**Figure 4.** Superposition of impact areas at explosion of ammonia fuel-air mixture in TOXI and ALOHA software systems (area of complete destruction of buildings (30%): (1) – TOXI, (4) - ALOHA; area of heavy destructions of buildings (20%): (2) – TOXI, (5) – ALOHA; area of complete divided glazing (26%): (3) – TOXI, (6) - ALOHA).

4. For LNG the pool fire is considered in two software systems too. Initial data are: environment temperature - 20°C, model - pool fire, total amount released - 4225 кг, substance temperature - 161.5°C. Impact areas at LNG pool fire in TOXI and ALOHA softwares are shown in the Figure 5.



**Figure 5.** Impact areas at LNG pool fire in TOXI (1, 2, 3) and ALOHA (4, 5, 6) software systems; (1) and (4) - 21%, (2) and (5) -18%, (3) and (6) - 17%.

Comparison of the calculations showed the allowable limits of discrepancy between the results for assessing the areas of toxic damage and explosive effects (from 7 to 30 % depending on the complexity of the model and the initial data).

#### 4. Future work

In our research works ALOHA software is the first block of the modular system of risk assessment which is based on risk assessment including domino estimation. The continuation of research works could be the quantitative assessment of cascade emergency development and the interval damage estimation.

#### 5. Conclusion

The assessment of impact areas is a part of technogenic safety management of potentially hazardous objects and territories in modern conditions. It can be carried out both in TOXI+Risk software which enables to calculate impact areas and particularly the risk and in ALOHA software which is applied for definition of impact areas. The results of the analysis showed that ALOHA software can be actively used in educational and in educational and practical purposes for practicing the skills of forecasting and immediate assessment of emergency situations, assessment of damage as a result of emergencies on territories of municipalities. The advantages of ALOHA software include the database of more than 1000 chemically hazardous substances including compounds, convenient topographical interface, free access to downloading of the software system. It allows conducting the scientific research works expanded up to the analysis of domino effect for critical infrastructures, risk assessment and working out the actions on management of this risk. The methodology of work in ALOHA software approved in the course of the master's degree program was developed.



## References

- [1] Guryev E S, Poluyan L V and Timashev S A 2014 Construction of dynamic risk maps for large metropolitan areas *J. of Risk Analysis and Crisis Response* **4(2)** pp 72–76
- [2] Guryev E S, Poluyan L V and Timashev S A 2011 Methodology of Constructing Dynamic Risk Maps for Large Metropolitan Areas *Proc. of the First Int. Conf. on Vulnerability and Risk Analysis and Management (ICVRAM 2011) and the Fifth Int. Symposium on Uncertainty Modeling and Analysis (ISUMA 2011)* pp 716–23
- [3] Timashev S A, Bushinskaya A V, Poluyan L V, Krimgold F, and Gheorghe A, 2012 Management (Governance) of regional risk based on unified criteria *World Congress on Risk “Risk and Development in a Changing World”* pp 73–74
- [4] Guryev E S, Poluyan L V and Timashev S A 2014 Construction of Dynamic Risk Maps for Large Metropolitan Areas *J. of Risk Analysis and Crisis Response* vol 4 **2** pp 72–76
- [5] Duijne F H, Aken D and Schouten E G 2008 Considerations in developing complete and quantified methods for risk assessment *Safety Science* **46** pp 245–254
- [6] Burns D S, Chynwat V, Moore W, Roumann S, Plitz A and Henley M V 2007 Improvement and Sensitivity Analysis of the Atmospheric Chemistry Module for Modeling TICs in SCIPUFF *Poster Paper at DOD BACIMO Conf.* **10**
- [7] Sykes R I, Cerasoli C P and Henn D S 1999 The representation of dynamic flow effects in a Lagrangian puff dispersion model *J. Hazard Mater* **64A** pp 223–247
- [8] Butler C J and Royle M 2000 *Experimental Data Acquisition for validation of a new vapour cloud fire (VCF) modeling approach* (Baxton: HSL)
- [9] Marshall V C 1987 *Major chemical hazards* (Chichester: Ellis Horwood) p 587
- [10] Titushkin V A, Guryev E S and Poluyan L V 2015 Toxic hazards of coke production *Coke and Chemistry* vol 58 **12** pp 487–491
- [11] 2017 *Software TOXI+<sup>Risk</sup> 5.1.5. Manual* p 310
- [12] *Field of Application and Functionality* Retrieved from <https://toxi.ru/polzovateli/dokumentatsiia>
- [13] Jones R, Lehr W, Simecek-Beatty D and Michael Reynolds R 2013 *ALOHA (Areal Locations of Hazardous Atmospheres) 5.4.4: Technical Documentation. U. S. Dept. of Commerce, NOAA Technical Memorandum NOS OR&R 43* p 96
- [14] 2016 *The CAMEO Software Suite ALOHA Example Scenarios National Oceanic and Atmospheric Administration Office of Response and Restoration Emergency Response Division* (Seattle, Washington) p 53
- [15] Shao H and Duan G 2012 Risk Quantitative Calculation and ALOHA Simulation on the Leakage Accident of Natural Gas Power Plant *Procedia Engineering* **45** pp 352–359
- [16] Tseng J M, Su T S and Kuo C Y 2012 Consequence Evaluation of Toxic Chemical Releases by ALOHA *Procedia Engineering* **45** pp 384–389 DOI:10.1016/j.proeng. 2012.08.175
- [17] Bhattacharya R and Ganesh Kumar V 2015 Consequence analysis for simulation of hazardous chemicals release using ALOHA software *Int. J. of ChemTech Research* vol 8 **4** pp 2038–2046
- [18] Timashev S A, Alekhin V N, Poluyan L V and Guryev E S 2015 Innovative Masters program “Safety of civil engineering critical infrastructures and territories” *Proc. of Intern. Conf. on Interactive Collaborative Learning* pp 1166–1170
- [19] Hanna S, Dharmavaram S, Zhang J, Sykes I, Witlox H, Khajehnajafi S and Koslan K 2008 Comparison of Six Widely-Used Dense Gas Dispersion Models for Three Recent Chlorine Railcar Accidents *Process Safety Progress* vol 27 **3**
- [20] 2005 *Collision of Norfolk Southern Freight Train 192 With Standing Norfolk Southern Local Train P22 With Subsequent Hazardous Materials Release at Graniteville NTSB/RAR-05/04 PB2005-916304 Notation 7710A 490* (South Carolina)